



Aviation Investigation Final Report

Location:	Atlanta, Georgia	Incident Number:	ENG14IA027
Date & Time:	September 21, 2014, 14:05 Local	Registration:	N669US
Aircraft:	Boeing 747	Aircraft Damage:	None
Defining Event:	Loss of engine power (total)	Injuries:	333 None
Flight Conducted Under:	Part 121: Air carrier - Scheduled		

Analysis

The airplane, a Boeing 747-451, had just taken off when the No. 4 engine, a Pratt & Whitney PW4056, lost power and then caught fire. The crew had to discharge two fire bottles into the engine's nacelle before the fire was extinguished. The airplane returned to the airport for a three-engine landing without further incident.

The disassembly of the engine revealed one 5th stage compressor blade was fractured transversely across the blade neck. The metallurgical examination of the blade confirmed a fatigue fracture that had originated from the aft concave side corner of the blade neck. The metallurgical examination also revealed evidence of grit blasting with embedded aluminum oxide media on the blade neck that, per the overhaul instructions, is a no grit blast area. Grit blasting of the blade root's contact surfaces with aluminum oxide media is a preparatory step for the application of plasma spray material, which is one of the repairs that was accomplished to the fractured blade.

The blade was overhauled by Turbine Overhaul Services (TOS), Singapore. TOS is an FAA-certificated Part 145 repair station for the overhaul and repair of turbine engine compressor blades and vanes. An audit of TOS's PW4000 5th stage compressor blade overhaul process showed that it conformed to the requirements except for the grit blasting operation that showed the grit blasting gun was being held too close to the blade. In addition, the masking process that was in use could result in no grit blast areas of the blade root being exposed to grit blasting.

The fire was caused by hydraulic fluid that leaked from the pressure line to pulse damper B-nut at the pump that loosened due to vibration following the compressor blade separation.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be:

Turbine Overhaul Service's aggressive grit blasting and incomplete masking of the blade root neck that allowed the no grit blast area being exposed during the overhaul of the blade resulting in blasting media being embedded in the blade root from which a fatigue crack developed. The fatigue crack propagated until separation of the blade occurred that resulted in a complete loss of engine power. The fire was caused by the B-nut on the hydraulic line from the fuel pump and pulsation damper loosening from engine vibration after the compressor blade separated spraying high pressure fluid into the engine compartment that ignited on the hot engine cases.

Findings

Personnel issues	Use of equip/system - Maintenance personnel
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Factual Information

History of Flight

Initial climb	Loss of engine power (total) (Defining event)
Initial climb	Powerplant sys/comp malf/fail
Initial climb	Fire/smoke (non-impact)

On September 21, 2014, about 1405 eastern daylight time, Delta Air Lines flight 295, a Boeing 747-451 airplane, N669US, experienced a loss of power that was followed by an in-flight undercowl fire in the No. 4 engine, a Pratt & Whitney (P&W) PW4056 turbofan, shortly after takeoff from the Hartsfield-Jackson Atlanta International Airport (ATL), Atlanta, Georgia. The airplane was making a maximum power takeoff from runway 27 Right. The pilots reported that the engine's operation was normal during the takeoff roll until just after liftoff. At about 400 feet above ground level (AGL), the pilots heard a loud bang, the airplane yawed, and they noted that the No. 4 engine's cockpit instruments indicated a loss of power. The pilot's accomplished the quick reference handbook (QRH) engine failure checklist and shutdown the No. 4 engine. At about 1,300 feet AGL, the No. 4 engine fire warning activated. The pilot's accomplished the QRH engine fire checklist and discharged the A fire bottle into the No. 4 engine's nacelle. When the fire warning did not go out after a minute, the pilots discharged the B fire bottle into the engine's nacelle. The fire warning extinguished about 20 seconds after the B fire bottle was discharged. The pilots dumped 280,000 pounds of fuel and returned to ATL for a three-engine landing on Runway 27 Right without further incident. The pilots stopped the airplane on the runway and after the fire department determined the engine was safe, they taxied the airplane back to the gate. The airplane was operating as a regularly scheduled international passenger flight on an instrument flight rules flight plan under the provisions of 14 Code of Federal Regulations part 121 from ATL to Narita International Airport, Tokyo, Japan.

Pilot Information

Certificate:	Airline transport; Commercial	Age:	54,Female
Airplane Rating(s):	Single-engine land; Single-engine sea; Multi-engine land	Seat Occupied:	Left
Other Aircraft Rating(s):	None	Restraint Used:	5-point
Instrument Rating(s):	Airplane	Second Pilot Present:	Yes
Instructor Rating(s):	None	Toxicology Performed:	No
Medical Certification:	Class 1 Unknown	Last FAA Medical Exam:	June 30, 2014
Occupational Pilot:	Yes	Last Flight Review or Equivalent:	July 30, 2014
Flight Time:	13562 hours (Total, all aircraft), 4176 hours (Total, this make and model), 142 hours (Last 90 days, all aircraft), 0 hours (Last 24 hours, all aircraft)		

Co-pilot Information

Certificate:	Airline transport	Age:	55,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	Seat Occupied:	Right
Other Aircraft Rating(s):	None	Restraint Used:	
Instrument Rating(s):	Airplane	Second Pilot Present:	Yes
Instructor Rating(s):	None	Toxicology Performed:	No
Medical Certification:	Class 1 Unknown	Last FAA Medical Exam:	April 3, 2014
Occupational Pilot:	Yes	Last Flight Review or Equivalent:	May 1, 2014
Flight Time:	12998 hours (Total, all aircraft), 293 hours (Total, this make and model), 170 hours (Last 90 days, all aircraft), 0 hours (Last 24 hours, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	Boeing	Registration:	N669US
Model/Series:	747 451	Aircraft Category:	Airplane
Year of Manufacture:	1990	Amateur Built:	
Airworthiness Certificate:	Transport	Serial Number:	24224
Landing Gear Type:	Tricycle	Seats:	403
Date/Type of Last Inspection:		Certified Max Gross Wt.:	892450 lbs
Time Since Last Inspection:		Engines:	4 Turbo fan
Airframe Total Time:	103501 Hrs	Engine Manufacturer:	P&W
ELT:		Engine Model/Series:	PW4056
Registered Owner:	WELLS FARGO BANK NORTHWEST NA TRUSTEE	Rated Power:	56750 Lbs thrust
Operator:	Delta Air Lines	Operating Certificate(s) Held:	Flag carrier (121)
Operator Does Business As:		Operator Designator Code:	DALA

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	Condition of Light:	Day
Observation Facility, Elevation:	ATL,1026 ft msl	Distance from Accident Site:	
Observation Time:	13:52 Local	Direction from Accident Site:	
Lowest Cloud Condition:	Scattered / 5000 ft AGL	Visibility	10 miles
Lowest Ceiling:	None	Visibility (RVR):	
Wind Speed/Gusts:	7 knots /	Turbulence Type Forecast/Actual:	/ None
Wind Direction:	300°	Turbulence Severity Forecast/Actual:	/ N/A
Altimeter Setting:	30.02 inches Hg	Temperature/Dew Point:	30°C / 17°C
Precipitation and Obscuration:			
Departure Point:	Atlanta, GA (ATL)	Type of Flight Plan Filed:	IFR
Destination:	(NRT)	Type of Clearance:	IFR
Departure Time:		Type of Airspace:	Class B

Airport Information

Airport:	HARTSFIELD - JACKSON ATLANTA I ATL	Runway Surface Type:	Concrete
Airport Elevation:	1026 ft msl	Runway Surface Condition:	Dry
Runway Used:	27R	IFR Approach:	Unknown
Runway Length/Width:	12390 ft / 150 ft	VFR Approach/Landing:	Unknown

Wreckage and Impact Information

Crew Injuries:	17 None	Aircraft Damage:	None
Passenger Injuries:	316 None	Aircraft Fire:	In-flight
Ground Injuries:	N/A	Aircraft Explosion:	None
Total Injuries:	333 None	Latitude, Longitude:	34.636943,-84.428054

Injuries to Persons

There were no reported injuries to the 4 pilots, 13 flight attendants, and 316 passengers on board.

Damage to Airplane

The airplane received minor thermal damage to the interior surfaces of the left and right core cowls. The remainder of the airplane did not sustain any damage.

Other Damage

No other damage was reported.

Airplane Information

The airplane was a Boeing 747-451, serial number (SN) 24224. The airplane was manufactured in 1990 and, at the time of the incident, had accumulated 103,501 hours since new. The airplane had a maximum takeoff gross weight of 870,000 pounds. The airplane's takeoff gross weight at the time of the incident was 866,200 pounds.

The airplane was equipped with four P&W PW4056 engines. The PW4056 is a dual-spool, axial-flow high bypass turbofan engine that features a 1-stage 94-inch diameter fan, 4-stage low pressure compressor (LPC), 11-stage high pressure compressor (HPC), annular combustor, 2-stage high pressure turbine (HPT) that drives the HPC, and a 4-stage low pressure turbine (LPT) that drives the LPC. The engine is 153.6-inches long, 97.5-inches in diameter, and has a dry weight of 9,420 pounds. The PW4056 engine has a takeoff thrust rating of 56,750 pounds flat-rated to 92°F (33°C) and a maximum continuous thrust rating of 47,970 pounds flat-rated to 86°F (30°C).

The No. 4 engine on the airplane was SN 727873. According to maintenance records, the engine was manufactured in January 1990 and had accumulated 56,240 hours and 7,080 cycles since new. The engine had been installed on the airplane on February 9, 2014, at ATL following an overhaul and had operated 2,738 hours and 320 cycles since it had been overhauled and installed on the airplane.

Communications

There were no reported communications issues.

Flight recorders

The airplane's digital flight data recorder (DFDR) was removed from the airplane and returned to the NTSB's Vehicle Recorder Laboratory for readout. The DFDR shows that at about 14:03:28, all four engines' power indications: engine pressure ratio (EPR), low pressure rotor speed (N1), high pressure rotor speed (N2), exhaust gas temperature (EGT), and fuel flow (Wf); began to increase from idle power and stabilized at maximum power at about 14:03:42. The DFDR data shows the airplane took off around 14:04:29. At 14:04:44; the No. 4 engine's EPR, N1, N2, EGT, and Wf were 1.5, 96.38 percent, 98.13 percent, 580°C, and 21,376 pounds per hour (pph) respectively. The DFDR data shows that at 14:04:46 and an altitude of about 364 feet AGL; the No. 4 engine's EPR, N1, N2, EGT, and Wf were 0.95, 61.13 percent, 81.38 percent, 587°C, and 21,312 pph. At 14:04:50; the EPR, N1, N2, EGT, and Wf were 0.95, 60.75 percent, 66.5 percent, 598°C, and 0 pph. The DFDR data shows that at 14:05:51 and an altitude of about 1,100 feet AGL, the No. 4 engine's fire warning activated and continued until 14:09:05.

Fire

The No. 4 engine experienced an undercowl fire. There was no fire damage to the airplane.

The left side of the engine did not have any fire damage, although there was soot on the LPT case, turbine exhaust case, and the turbine case cooling manifolds. The right side of the engine was sooted and fire damaged between the intermediate case and the turbine exhaust case. Forward of the raceway supporting the fuel and hydraulic lines, the fire damage primarily between the top of the engine and the engine's horizontal centerline. Aft of the fuel and hydraulic line raceway, the fire damage was primarily between the horizontal centerline and the bottom of the engine. The damage in these areas consisted of the loss of clamp cushioning material, wire insulation, and fire loop support isolators.

The fuel line was intact and the insulation/fire sleeve remained in place. The insulation at the lower end had a small area of white ash, the center section had an eroded appearance with multiple cracks, and the upper section eroded down to the fabric material. The section of the fuel line that was covered by the spray shield was less distressed than the parts of the fuel line that was not covered by the spray shield. The pressure check of the fuel system showed that there was no leakage.

The area around where the hydraulic pressure line connects to the hydraulic pump and pulsation damper was wetted and lacked the soot and debris noted on adjacent areas. It was reported that when the engine was being removed from the airplane, that the hydraulic pressure line's B-nut at the pulsation damper was dripping fluid that continued until the B-nut was tightened 1 1/2 turns. The two turbine cooling air lines between the high pressure turbine case and the hydraulic lines that were in line with the B-nut at the pulsation damper were significantly cleaner than adjacent areas.

The left and right engine core cowls did not have any burn throughs or areas of heat discoloration on the exterior. The exterior of the left side core cowl had a soot trail from the pre-cooler exhaust vent. The interior of the pre-cooler exhaust duct and the vent fins were sooted. The interior of the left side core cowls had soot and white-colored deposits along the top in the bay above the pre-cooler exhaust duct. The interior of the left side core cowl had sooting and white-colored deposits on the forward two rib bays between the horizontal centerline and the top and the full vertical length of the aft rib bay. The exterior of the right side of the core cowl had black-colored trails of a dry, tacky material extending aft from the blow out doors to the rear edge of the cowling. The right hand core cowl had almost all of the interior surface coated with soot or white-colored deposits.

Tests and Research

The No. 4 engine was removed from the airplane and disassembled at Delta's Technical Operations Center, Atlanta, Georgia in the presence of the Powerplants Group. The disassembly revealed one 5th stage compressor blade that was fractured transversely through the blade neck. The fractured blade's root section remained in the blade slot, but the liberated portion of the blade was not found. Most of the fracture surface had two distinct patterns of elliptical marks that radiated from the blade's aft concave side corner. The elliptical marks radiated from the aft corner to the forward side and across the ribs between the lightening holes to the convex side. All of the other 5th stage compressor blades were fractured between 1.5- and 3.5-inches above the blade root platform. All of the other high pressure compressor blades, from the 6th stage rearward were spoon-shaped and appeared have had the airfoils burned off.

The fractured blade was examined at the NTSB's and P&W's materials laboratories. The metallurgical examination revealed the blade had separated from a high cycle fatigue fracture that had originated in the aft concave side corner of the blade neck. The metallurgical examination showed that the blade's

material conformed to the required alloy and that the plasma spray and anti-gallant coatings were present and the thickness of the coatings conformed to the requirements. The visual examination of the fractured blade's neck as well as the necks on several other 5th stage compressor blade roots removed from the engine showed evidence of grit blasting. The energy dispersive spectrographic analysis of the area that appeared to be grit blasted produced an aluminum and oxygen-rich spectra.

The maintenance records showed that the fractured 5th stage compressor blade was among a batch of 40 blades that had been overhauled by Turbine Overhaul Services (TOS), Singapore in October 2013. (TOS, which is a joint venture between P&W and Singapore Technologies Aerospace, is an FAA-approved Part 145 repair station that specializes in the repair and overhaul of turbine engine compressor and turbine blades and vanes.) As part of the overhaul process, the plasma spray coating on the blade roots was removed and replaced. As part of the preparation for the application of the plasma spray, the surface of the blade root is grit blasted with aluminum oxide media. The blade root neck is identified in the repair procedures as a no-grit blast area.

TOS, after being notified of this incident and the metallurgical finding that the fractured blade root neck had evidence of grit blasting with aluminum oxide media, conducted an audit of its PW4000 5th stage compressor blade overhaul and repair processes. The audit revealed TOS's PW4000 5th stage compressor blade overhaul and repair processes conformed to the requirements except for the aluminum oxide grit blasting surface preparation prior to the application of the plasma coating. The audit revealed the operator held the grit blasting gun about 2 inches from the surface instead of the specified 4 to 6 inches. TOS reported that prior to the incident, it had developed a gage block to more accurately apply the masking tape that is used to prevent overspray when grit blasting. In addition, TOS reported that it had also developed a metal shield to further protect the blade root neck from overspray.

Administrative Information

Investigator In Charge (IIC):	Hookey, Gordon
Additional Participating Persons:	David Keenan; Federal Aviation Administration; Washington, DC Katheryn Malatek; Federal Aviation Administration; Burlington, MA Joshua Migdal; Delta Air Lines; Atlanta, GA Christopher J Jarrette; Delta Air Lines; Atlanta, GA Van J Winters; Boeing; Seattle, WA Douglas Zabawa; Pratt & Whitney; East Hartford, CT Patrick McHugh; Air Line Pilots Association; Atlanta, GA
Original Publish Date:	September 28, 2016
Last Revision Date:	
Investigation Class:	Class
Note:	The NTSB did not travel to the scene of this incident.
Investigation Docket:	https://data.nts.gov/Docket?ProjectID=90120

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The NTSB does not assign fault or blame for an accident or incident; rather, as specified by NTSB regulation, “accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties ... and are not conducted for the purpose of determining the rights or liabilities of any person” (Title 49 *Code of Federal Regulations* section 831.4). Assignment of fault or legal liability is not relevant to the NTSB’s statutory mission to improve transportation safety by investigating accidents and incidents and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report (Title 49 *United States Code* section 1154(b)). A factual report that may be admissible under 49 *United States Code* section 1154(b) is available [here](#).